Boron

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Contents

1 Natural Boron

Natural boron is composed of two isotopes. It is about 20 per cent B^{10} and 80 percent B^{11}. Natural boron can be enriched to nearly pure B^{10}. The waste product, which is called depleted boron, is nearly pure B^{11}. Enriched boron or B^{10} is used in both radiation shielding and in boron neutron capture therapy. B^{10} has a large cross section for neutron capture. In boron neutron capture therapy, a compound containing B^{10} is placed in or near a tumor. The patient is treated with a relatively low dose of thermal neutrons. A neutron captured by the boron nucleus causes a nuclear reaction with the emission of a short range alpha particle. These alpha particles bombard and kill the tumor cells.

2 Boric Acid

Boric acid is the weak acid

$$H_3BO_3$$

and is the starting material for producing many boron compounds.

3 Borax

Borax, also known as sodium borate, sodium tetraborate, or disodium tetraborate, is an important boron compound, a mineral, and a salt of boric acid. It is usually a white powder consisting of soft colorless crystals that dissolve easily in water.

A mixture of borax and ammonium chloride is used as a flux when welding iron and steel and when brazing. It lowers the melting point of the unwanted iron oxide (scale), allowing it to run off. Borax is also used mixed with water as a flux when soldering jewelry metals such as gold or silver. It allows the molten solder to flow evenly over the joint in question. Borax is also a good flux for 'pre-tinning' tungsten with zinc - making the tungsten soft-solderable

Borax has a wide variety of uses. It is a component of many detergents, cosmetics, and enamel glazes. It is also used to make buffer solutions in biochemistry, as a fire retardant, as an anti-fungal compound for fiberglass, as an insecticide, as a flux in metallurgy, and as a precursor for other boron compounds.

Common borate salts include sodium metaborate, $NaBO_2$, and sodium tetraborate, $Na_2B_4O_7$

4 Thermal Neutrons

Thermal neutrons have an energy of about 0.025 eV. This relates to the energy range of gas molecules that obey the Maxwell velocity distribution.

Fast neutrons have an energy between 1 eV, and 1 MeV. Slow neutrons have an energy less than or equal 0.4 eV. Epithermal neutrons have an energy from 0.025 to 1 eV. Hot neutrons have an energy of about .2 eV. Cold neutrons have an energy from 5x10-5 eV to 0.025 eV. Very cold neutrons have an energy from 3x10-7 eV to 5x10-5 eV. Ultra cold neutrons have an energy less than 3x10-7 eV. Continuum region neutrons have an energy from 0.01 MeV to 25 MeV. Resonance region neutrons have an energy from 1 eV to 0.01 MeV. Low energy region neutrons have an energy less than 1 eV.

5 Cross Section

Reference:
Lamarsh John R. **Introduction to Nuclear Reactor Theory**, Addison-Wesley 1966, p18.

Consider a target of area A and thickness d. Let N be the number of target atom per unit volume. I is neutron flux, the number of neutrons in the uniform beam that hit the target per cm^2 per sec. Then the number of reactions per second is

$$r = \sigma I N A d,$$

where σ is a proportionality constant called the cross section. σ has the dimension of area (cm^2).

IA neutrons hit the target per second, and

$$r = \sigma I N A d$$

of them interact. The probability that any one neutron interacts is then

$$\frac{\sigma I N A d}{I A} = \left(\frac{\sigma}{A}\right) N A d.$$

Because NAd is the number of atoms in the target, σ/A is the probability per target nucleus of an interaction with a neutron.

So suppose a barn door has area A, and a target of area σ is painted on the door. Suppose one throws a baseball at the door and it is equally likely to hit the door at any point. Then the probability of the baseball hitting the target is clearly

$$\frac{\sigma}{A}.$$

Thus cross sections are measured in a unit of area called the barn, which is equal to

$$10^{-24} cm^2,$$

which is on the order of the cross sectional area of an atom.

The following couple of paragraphs to papers on determining the cross section values of Boron for neutrons of various energies.

The Capture Cross Section of Boron for Neutrons of Energies from 0.01 ev to 1000 ev R. B. Sutton *, B. D. McDaniel , E. E. Anderson , and L. S. Lavatell, Phys. Rev. 71, 272 - 272 (1947) University of California, Los Alamos Scientific Laboratory, Santa Fe, New Mexico, Received 23 January 1947. 1947 The American Physical Society

URL: http://link.aps.org/doi/10.1103/PhysRev.71.272 DOI: 10.1103/PhysRev.71.272

The value obtained for the boron scattering cross section was

$$4.2 \times 10^{-24} cm^2.$$

In the Wikipedia article on Nuclear Cross Sections, we find the following material, which contains a small error:

The nuclear reaction rate is

$$r = \Phi \sigma \rho,$$

where r is the number of reactions per second per volume (cm^3), Φ is the flux of the incident particles in particles per second per area (cm^2), σ is the cross section (in barns or cm^2), and ρ is the density of target nuclei in nuclei per volume (cm^3). Thus the cross section σ is defined by this formula. This formula assumes that the flux does not change as the target nuclei are penetrated. This could not be the case for an infinitely thick target, or for a target of extreme thickness.

This Wikipedia information "(in barns or cm^2)" is not quite right, because in the formula, if we are using the csg system, σ must always be given in cm^2, so as to make the equation have consistent units. If values in barns were used, a wrong answer would be obtained. So say we have a cross section of 67 barns. Then we would enter for σ in the formula the value $\sigma = 67 \times 10^{-24} cm^2$. I may attempt to edit the Wikipedia article and correct the error.

6 BNC, Boron Neutron Capture

In Boron Neutron Capture, the nucleus of the Boron 10 atom captures a neutron and the atom becomes an excited Boron 11 atom. The Boron 11 atom then undergoes a fission reaction as follows:

$$B^{10} + n \rightarrow B^{11}_{*} \rightarrow Li^7 + He^4 + \gamma + 2.4MeV.$$

Now the He^4 is an α particle, which is quite short range and lethal to cells. The γ photon is not short range, but its intensity is low. The BNCT (Boron Neutron Capture Therapy) uses this reaction for a medical therapy.

Reference: Condensed version of the 79th Faculty Research Lecture Presented by Professor M. Frederick Hawthorne. bnct2.pdf, or

`http://nanomed.missouri.edu/researchpapers/BNCT.pdf`

7 New Form of Boron

`http://www.nytimes.com/2009/02/03/science/03boron.html?_r=2&ref=science`

boronnytimes.pdf

Artem R. Oganov, a professor of geosciences at Stony Brook University.

(1)α Boron

(2)β Boron

(3)$T - 192$

(4) New recently discovered 4th form, γ Boron.

8 Genetic Algorithm

This algorithm follows the process of biological evolution to arrive at a solution of an optimization problem.

Given:

(1) A structure S.

(2) A fitness function value f(S) to be minimized, say energy.

(3) A method of random mutations of the structures.

$$S \rightarrow S'$$

(4) Mating of promising structures $S_1 + S_2 \rightarrow S'$

(5) Select the new structure if $f(S') < f(S)$.

(6) Back up to a previous structures if the current chain of structures is not leading to sufficient optimization.

(7) Crossover, portions of structures interchanged.

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3.2   Genetic Algorithm considerations
3.2.1 Data representation
3.2.2 Fitness function
3.2.3 Starting conditions
3.2.4 Mutation
3.2.5 Mutation as a variable
3.2.6 Crossover
3.2.7 Selection
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Reference:

Inorganic Crystal Structure Prediction a Dream Coming True? Anton Meden Faculty of Chemistry and Chemical Technology, University of Ljubljana, Akereva 5, SI-1000 Ljubljana

`http://acta.chem-soc.si/53/53-2-148.pdf`

9 Cross-linking a Polymer, With Boron

Elmer's glue (polyvinyl acetate) and Borax can be used to cross-link a polymer, and make a material similar to silly putty.
http://www.stevespanglerscience.com/experiment/00000039

Ethylene is the compound H_2CCH_2, an unsaturated alkene hydrocarbon with a carbon double bond.

Vinyl is the univalent chemical radical CH_2CH, derived from ethylene.

The acetate anion, $[CH_3COO]-$, is a carboxylate and is the conjugate base of acetic acid (vineger), a carboxylic acid.. The acetate ion is formed by the deprotonation of acetic acid:

$$CH_3COOH \rightarrow CH3COO^- + H^+$$

polyvinyl acetate, PVA, is the polymer chain

$$(H_2CCHOOCCH_3)_x,$$

consisting of x similar links.

As an emulsion in water, PVA is sold as an adhesive for porous materials, particularly wood, paper, and cloth. It is the most commonly used wood glue, both as "white glue" and the yellow "carpenter's glue."

PVA is widely used in bookbinding and book arts due to its flexibility, and because it is non-acidic, (unlike many other polymers) is used extensively in paper, paint and industrial coatings when it is referred to as vinyl acrylic.

PVA is slowly attacked by alkali, forming acetic acid as a hydrolysis product.

Boron compounds like boric acid or borax will form tackifying precipitates by causing the polymer to cross-link.

Reference for polyvinyl acetate:

`http://en.wikipedia.org/wiki/Polyvinyl_acetate`

Reference for making a silly-putty like material by cross-linking polyvinyl acetate:

`http://www.stem2.org/je/slime.pdf`

10 Boron Shot Tower

This relates to Maurice Smith's anecdote, where he said that the Boron shot that he produced with his melting tower, was for the Grable nuclear weapons test. But the original Grable test was conducted in 1953, Maurice would have been quite a prodigy. It was a later test he was referring to ((upshot_knothole_grable, W48, 155 Artillary Shell). Here are some YouTube videos of the original Grable test and a wikipedia article:

http://www.youtube.com/watch?v=neom4tB99Bo

http://www.youtube.com/watch?v=hfEMnx-Nz-w

http://en.wikipedia.org/wiki/Nuclear_artillery

11 Bibliography

There is some information on simulated annealing algorithm, which is similar to the genetic algorithm in the **Numerical Recipes** books.

The capture cross section of natural boron for slow neutrons has been measured by a dynamic method, in which the decay constant of neutrons in a water tank was plotted against the concentration of added borax. Samples were compared with a standard boron oxide in GLEEP at the Atomic Energy Research Establishment, Harwell. The result is quoted as $\sigma_B = 760 \pm 3$ barns for the A.E.R.E. sample of natural boron oxide.

[1]Vose, Michael D. , **The Simple Genetic Algorithm : Foundations and Theory** , LHL QA402.5 .V67, 1999. .
[2]Lamarsh John R. , **Introduction to Nuclear Reactor Theory** , Addison-Wesley 1966, p18.
[3]Meden Anton, **Inorganic Crystal Structure Prediction a Dream Coming True?** Faculty of Chemistry and Chemical Technology, University of Ljubljana, Akereva 5, SI-1000 Ljubljana
[4]Hawthorne Frederick **Condensed version of the 79th Faculty Research Lecture Presented by Professor M. Frederick Hawthorne.** http://nanomed.missouri.edu/researchpapers/BNCT.pdf, or bnct2.pdf
[5]R. B. Sutton *, B. D. McDaniel , E. E. Anderson , and L. S. Lavatell, **The Capture Cross Section of Boron for Neutrons of Energies from 0.01 ev to 1000 ev** Phys. Rev. 71, 272 - 272 (1947) University of California, Los Alamos Scientific Laboratory, Santa Fe, New Mexico, Received 23 January 1947. 1947 The American Physical Society URL: http://link.aps.org/doi/10.1103/PhysRev.71.272 DOI: 10.1103/PhysRev.71.272
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[6]Press William h, Teukolsky Saul A, Vetterling William, Flannery Brian P, **Numerical Recipes In Fortran 77**, 2nd Edition, 1996, (This book is available in several editions and versions). Chapter 10 has a section on Simulated Annealing, which is quite similar to Genetic Algorithm methods. These methods are not cut and dried, but require a certain amount of creativity for a given problem.
[7]Napier M. J. (Michael) **Boron Shot Grading and Inspecting.** BDX613155, NTIS (National Technical Information Center), 1970. For abstract, see NSA 24 24, number 53020.
[8]Smith Maurice L, Smith Robert M **Process For Recovering Filler From Polymer.** United States Patent 4,091,077, May 23, 1978.